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"CAMERA FINISH" AT THE RACE TRACK

By Irvine C. Gardner

ABSTRACT

Cameras have been generally installed at race tracks to automatically photograph the finishes of the races. If a race is too close to permit placing the horses by visual observation the judges may use photographs as a basis for their decision. There has been considerable criticism of the camera, and some have questioned the accuracy of the pictures that are obtained. A discussion of possible sources of errors and a quantitative appraisal of their importance are given. The conclusion is that relatively simple precautions make the camera a reliable instrument for determining the outcome of a race. In installations that have been examined these precautions have received adequate attention.

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I. INTRODUCTION

It is not unusual for the finish of a race to be so close that the judges are unable to agree upon the order in which the horses should be placed. To meet this difficulty recourse has been made to the use of cameras which automatically photograph the finish of the race and which provide photographs upon which the judges may base their decisions. This procedure has been so generally adopted that substantially all race tracks are equipped with camera installations, and their use has resulted in the coinage of the newspaper expression "camera finish" and "photo finish" to designate a finish so close that the judges are unable to reach a decision without an appeal to the photographic evidence.

This universal installation of photographic equipment at the tracks should not be understood to imply that their introduction has met with the general approval of followers of the races. On the contrary, many decisions based upon the camera have been caustically criticized, and these criticisms have been given coherence by the newspapers, which have printed many comments intended to indicate that the cameras, for some reason not detailed, favor the outside horse, that is, the horse farthest from the rail. As a result, a curious situation has developed.

The judges on the one hand, although most favorably situated to view the finish of a race, readily admit their inability to place the horses with certainty in a particularly close heat and voluntarily appeal to the camera for assistance. On the other hand, the spectators, less favorably situated than the judges, do not hesitate to affirm their ability to correctly place the horses by visual observation and, on the basis of their decision, accuse the camera of inaccuracy. As a consequence, the New York State Racing Commission has asked the National Bureau of Standards to investigate the installations at the different New York tracks. In view of the considerable interest in the decisions of the camera, as evidenced by the frequency of comment in the daily newspapers, it has been considered desirable to set forth the conditions necessary for the correct photographic representation of the finish of a race and also to estimate, quantitatively, the errors which may result from the neglect of certain precautions.

Before proceeding with the consideration of these conditions governing accuracy of performance, it is advisable to set forth the restrictions governing the choice of material for this presentation. There are many factors that determine the desirability of a given type of camera installation. Important requirements are certainty of operation, rapidity of operation, and accuracy of representation of the finish. Of these, the first two depend upon such details as the type of photo-electric cell unit employed to actuate the camera, the excellence of design and workmanship of the mechanical parts, the presence or absence of automatic apparatus for developing the film, the enlarging apparatus, and other features of construction. As the present-day camera installations are far from standardized in construction or operation, no important general conclusions regarding certainty and rapidity of operation can arise from a consideration of installations at a few tracks. Each installation must be examined and judged upon its merits. All of the installations, however, have the principle in common that the accuracy of a photograph of the finish depends upon the operation of a lens and shutter, elements for which considerable standardization already exists. Examination of a few installations, therefore, readily leads to conclusions which in these respects, are valid for all. Consequently, this paper will be definitely restricted to a consideration of the factors that govern the production of photographs that will correctly represent the finish of a race.

The factors which may cause a photograph to be incorrect or misleading are: (1) action of the shutter; (2) relative position of camera and finish line; and (3) perspective.

II. ACTION OF THE SHUTTER

1. SINGLE-EXPOSURE CAMERA

In the single-exposure or "still" camera a focal-plane shutter is commonly employed. With this type of shutter the exposure is made through a narrow slit which rapidly travels across the plate. It follows that the entire picture is not taken at the same time but that different parts of the film are successively exposed. In a typical focal-plane shutter as used for fast moving objects, the width of the travelling slit is $\frac{1}{8}$ inch. If the exposure is $\frac{1}{1000}$ second the slit travels at a rate of 62.5 inches per second. If the direction of travel of the slit is parallel to the longer side of a 4 by 5 plate, one edge exposed 0.08 second later than the opposite edge. It is important

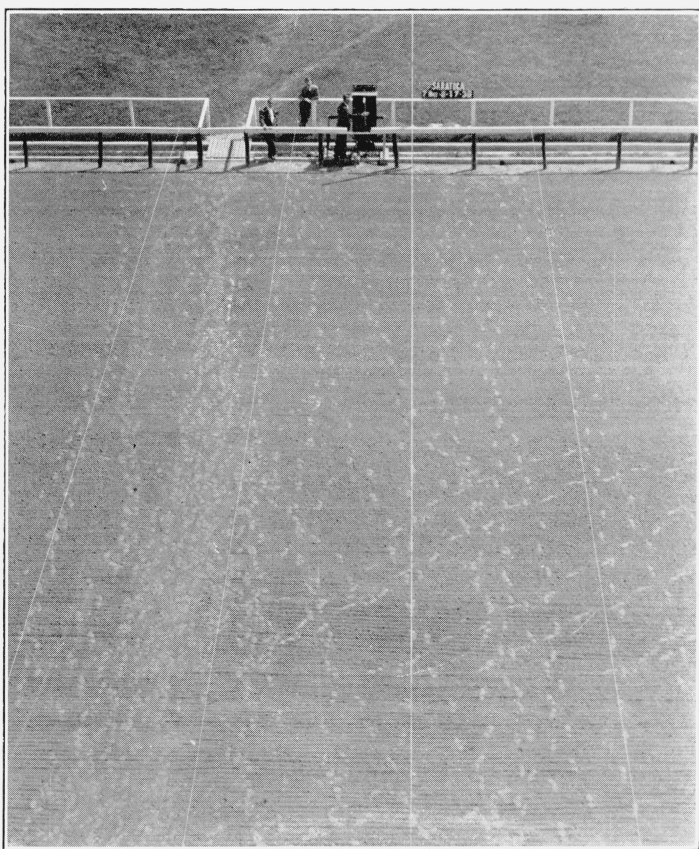


FIGURE 1.—A photograph of the track at Saratoga Springs made with one of the recording cameras.

The vertical white line is the finish line under which the horses pass. The three lighter lines are cords temporarily stretched, for this photograph, parallel to the finish line and spaced 10 feet apart. The convergence of these lines is illustrative of the extent to which parallel lines are rendered convergent by perspective. The enlargement of a finish, as prepared for the judges, shows only a small area of this photograph, next to the rail, enlarged approximately 5 diameters.

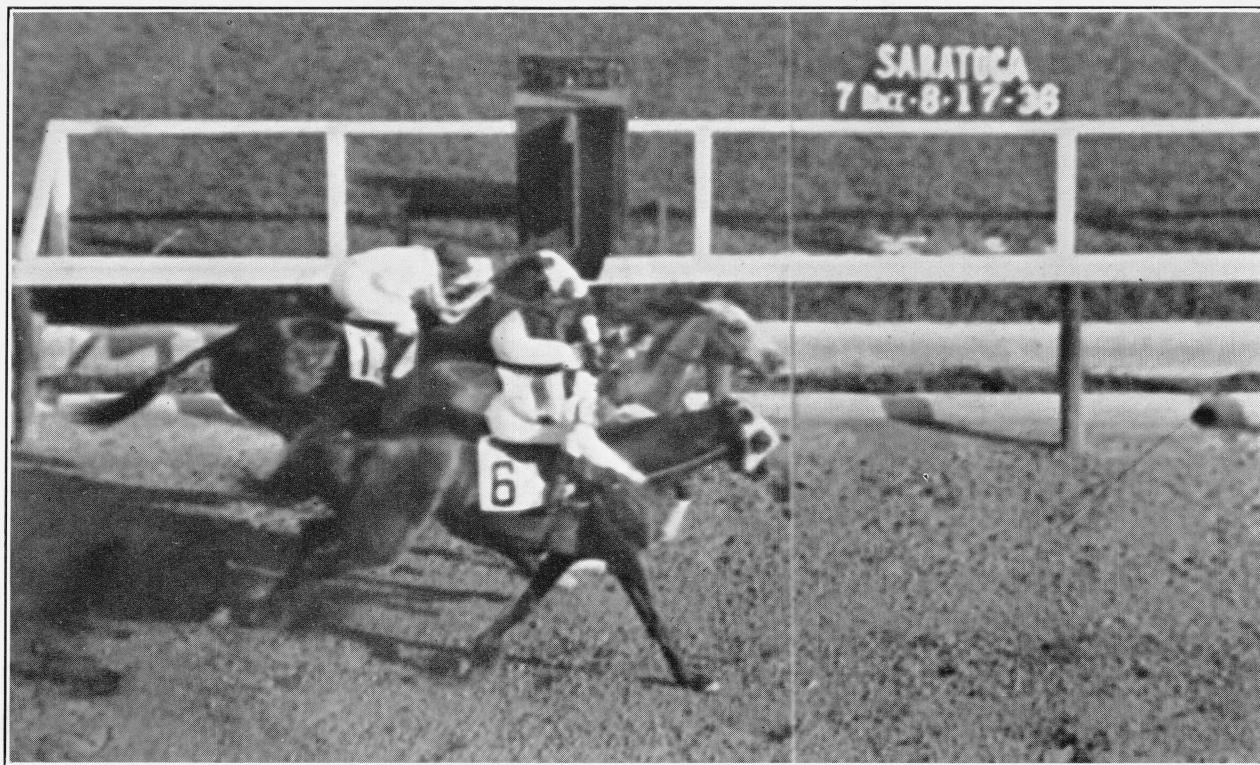


FIGURE 3.—*A reproduction of a portion of the photograph of the finish of the eleventh race on August 17, 1936, at Saratoga Springs.* The outside horse, Jaber, numbered 6, was judged to be the winner. The newspapers, in criticizing this decision, stated that the spectators generally believed that Captain Jinks, the horse nearer the rail, should have been declared the winner. Analysis indicates that the photograph must have placed the two horses correctly in this race.

therefore, that the direction of travel of the shutter be such that this difference in time will introduce no error. For correct results the direction of travel must be such that the entire finish line is photographed at the same instant. This is generally understood, and it is believed that this rule is followed at all camera installations.

Nevertheless, since the use of a vertically moving shutter has been often considered, it is interesting to determine, quantitatively, the errors which might result from a violation of this principle. Figure 1 is an actual photograph made at the Saratoga Springs track with the regular camera installation. Three lines were stretched across the track, parallel to the finish line and spaced 10 feet apart. These lines afford a convenient scale for the interpretation of the photograph and also show, by their convergence, the result of perspective. Figure 2 is a tracing of the essential parts of this photograph, inverted because this is the way the image appears on the ground glass. It will be assumed that two horses are running a dead heat with their noses at the finish line at *X* and *Y*. These positions have been selected to correspond to points approximately 5 and 15 feet from the rail. (It will be understood that this photograph shows a large width of the track which is never used at the time of the finish of a race. Actually, the competing horses in a near dead heat will often be crowded together and the leaders are seldom laterally separated as much as 10 feet, measured along the finish line.) The horizontal slit of the focal-plane shutter is shown at *AB* in a position to photograph *Y*, the outside horse. The horse *X*, nearer the rail, will not be photographed until the slit has travelled downward a distance of approximately $\frac{3}{4}$ inch on the film. With the slit travelling 62.5 inches per second this corresponds to a time interval of 0.012 second, during which the horse, travelling at an average speed of 55 feet per second, will have advanced 0.66 foot or approximately 8 inches. Consequently, in a dead heat, with this arrangement, the horse next to the rail will be favored, and he will be given a spurious lead of 8 inches.

In considering this result it should be noted that the values have been consistently chosen to yield a large error. Actually, the exposure will probably be 0.001 second, in which case the shutter speed

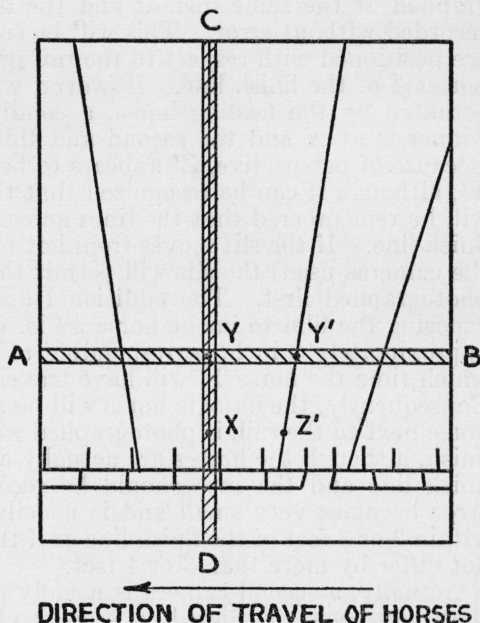


FIGURE 2.—A tracing of the essential portions of figure 1, inverted to bring it into its position as imaged on the ground glass of the camera.

As a result of the inversion the direction of travel of the horses is from right to left on this page. *AB* represents one position of the slit of a focal-plane shutter for which the slit travels in a vertical direction. *CD*, similarly represents the slit of a focal-plane shutter for which the slit travels horizontally. This illustration is reduced to about one-half. Measurements given in the text were made on original 4- by 5-in. negative.

is doubled. Also the two horses running the dead heat may have crowded as close to the rail as possible so that they are 5 feet instead of 10 feet apart (measured along the finish line). In such a case the error resulting from this worst possible installation of the focal-plane shutter will be 2 inches. If the vertically travelling focal-plane shutter moves upward instead of downward the outside horse will be favored but the amount of the error remains the same.

Greater interest is attached to the focal-plane shutter as commonly installed with a vertical slit travelling horizontally. In figure 2, *CD* indicates such a vertical slit assumed to be travelling from left to right. This is the usual direction of travel. The entire finish line is photographed at the same instant and the dead heat or a close finish is recorded without error. This will be so, no matter where the horses are positioned with respect to the rail provided they are in the neighborhood of the finish line. However, with a single-exposure camera, actuated by the leading horse, a condition may arise in which the winner is at *X* and the second and third horses are at *Y'* and *Z'*. Because of perspective, *Z'* appears to be nearer the finish line than is *Y'*, although it can be recognized that they are actually even since it will be remembered that the lines across the track are parallel to the finish line. If the slit moves from left to right (the usual direction in the cameras used) the slit will permit the horse next to the rail to be photographed first. The additional distance the slit travels before exposing the film to image horse *Y'* is, with the horses 10 feet apart, approximately $\frac{1}{8}$ inch, corresponding to a lag of 0.002 second, during which time the horse *Y'* will have travelled approximately $1\frac{1}{4}$ inches. Consequently, the outside horse will be shown $1\frac{1}{4}$ inches ahead of the horse next to the rail, if photographed when both are 10 feet from the finish, although the horses are actually at the same distance from the finish line and the race should be recorded as a dead heat. This error becomes very small and is usually negligible if the horses are within 2 or 3 feet of the finish line or if their distances from the rail do not differ by more than 3 or 4 feet.

Actually, a second camera is usually provided and, in the example that has been considered, a second photograph would have been made with the horses *Y'* and *Z'* at the finish line. This procedure should always be followed as, otherwise, the horses *Y'* and *Z'* are photographed before they have completed the race, and their relative positions may change during the remaining few feet which they are to run.

Even when the second camera is provided, however, in general, it will not function unless there is no overlapping between the leading horse and the next two. Consequently, cases may occur in practice when second and third places will have to be awarded on the basis of a picture which shows the horses nearly a length from the finish line. If the horses *Y'* and *Z'* in such a case are assumed to be not more than 8 feet from the finish line and are separated laterally by a distance of 10 feet, this will introduce an error of approximately 1 inch in the relative positions of the two horses. Usually the lateral spacing is much less than 10 feet and the horses will be less than 8 feet from the finish line and the error correspondingly reduced.

2. MOTION-PICTURE CAMERA

The motion-picture-camera shutter is a rotating disk with a radial aperture. This is mounted back of the lens and, because of the short focal length, it cannot be far from the focal plane. Consequently, the shutter acts in a manner intermediate between that of the between-the-lens shutter and the focal-plane shutter. The opening in the rotating disk is so large that the entire frame is simultaneously exposed during a part of the exposure, but the exposure begins at one edge of the frame and ends at the opposite edge. The ordinary motion-picture camera takes 20 pictures per second and approximately half the time is required for advancing the film between exposures. Consequently, the over-all duration of a single exposure is 0.025 second, and the instants of exposure for different parts of the frame cannot differ by an amount greater than this. For the 4 by 5 focal-plane shutter that has just been considered the analogous difference in time is 0.08 second. Therefore, the errors arising from nonsimultaneous exposure of the film are less than one-third the corresponding errors for the single-exposure camera. A camera operating at normal speed, however, is not satisfactory in the present case because the horses advance approximately 30 inches between exposures, and one cannot be certain of obtaining pictures with the horses sufficiently near the finish line. Therefore, the speed of the camera is stepped up to two or three times normal and all of the errors are further reduced to a negligible value. Furthermore, in the consideration of the single-exposure camera, it will be recalled that considerable attention was given to the condition arising when the second and third horses are closely matched and less than a length behind the first. In such a case the judges must rely on a photograph showing the first horse at the finish line and the second and third horses at small distances from it. With the single-exposure camera this introduces a systematic although very small error in placing the second and third horses. This error is usually negligible. With the motion-picture camera this source of error does not arise because the camera operator may select, for enlargement, frames showing the second and third horses when at the finish line.

III. RELATIVE POSITION OF CAMERA AND FINISH LINE

The camera is mounted high above the track at the back of the stand, over a prolongation of the finish line. The finish line is 10 or 12 feet above the track and is supported at the end over the rail by an upright carefully guyed so that it is accurately vertical. The line and the upright determine a vertical plane extending across the track and the horses are placed in the order in which their noses come into this plane. The camera must be so positioned that this plane is photographed as a vertical line in the picture. It is not necessary to make an elaborate survey in order to determine the correct placing of a camera as each photograph of a race indicates whether or not the camera is correctly placed. On the photograph the image of the overhead finish line should be exactly superposed upon that of the upright. Close examination of the photograph from which figure 3 was copied will show that this condition is not exactly fulfilled, although the defect is quite insignificant in amount and may not be apparent in the reproduction.

IV. PERSPECTIVE

The four converging lines of figure 1 are representative of parallel lines on the track. The apparent convergence is not caused by a defect in the lens but is a necessary consequence of the placing of the camera. The photograph gives the appearance of the track as viewed from the camera booth in true perspective. This apparent displacement arising from perspective becomes greater at greater distances from the finish line, but at the finish line it is entirely absent.

If a single-exposure camera is employed, the interruption of the beam of light falling upon the photoelectric cell should cause the picture to be taken when the horse is at the finish line. Figure 3 is a sample photograph from the Saratoga Springs track, and is an excellent example of good timing of the instant of exposure. If the second and third horses are less than a length behind the first horse no exposure will be available showing them at the finish line. This case has already been discussed from the standpoint of errors which may be introduced into such a picture because of the use of a focal-plane shutter. But even if the picture is correctly made and free from error arising from the action of the shutter there is still the possibility of an incorrect decision because of the failure to allow for the effect of perspective. If, as before, it be assumed that one horse is 10 feet farther from the rail than another and that both are approximately 5 feet from the finish, the error from the neglect of perspective will be approximately 1 foot and in favor of the horse next to the rail. This has been determined by scaling the value from figure 2 and, therefore, applies only to the installation at Saratoga Springs, but errors of approximately the same magnitude may be expected at other tracks.

The allowance for perspective, however, can be easily and accurately made. As a preliminary step, stretched parallel strings a foot apart and at the average height of a horse's nose, on the side of the finish from which the horses approach, can be photographed with the camera in its regular position and the resulting negative enlarged to the same size, as is customary for the purposes of the judges. The pattern of lines, including the finish line, should then be reproduced on a piece of transparent celluloid and made available to the judges. In a doubtful case the celluloid should be placed over the photograph with the finish lines coinciding. A dead heat will be indicated if two horses have their noses on the same member of this family of converging lines.

As already mentioned, if an installation is equipped with a motion-picture camera, and the close decision is between the second and third horses, a frame should be selected for enlargement in which these two horses are at the finish line. This completely eliminates any inaccuracy of interpretation arising from perspective, and the possibility of selecting such a frame is one of the important advantages of the motion-picture camera installation.

V. CRITICISM OF CAMERA DECISIONS

It has already been pointed out that the criticism of camera decisions has been sufficiently general to gain frequent mention in the newspapers. A hypothesis has gradually evolved that the camera favors the outside horse. The photograph shown in figure 3 is a case in point. On the basis of this photograph the decision was

awarded to Jaber, horse 6. The camera was properly mounted with the focal-plane shutter travelling in a horizontal direction. The photograph itself contains evidence that the other conditions are satisfactorily complied with. The camera actuating device operated to take the picture when the horses were at the finish line. The photographs show exactly what the judges would have seen had they been situated above the finish line and had they been able to judge the rapidly moving horses with the accuracy of the camera. The following morning one of the more conservative news items regarding the decisions says:

The first public dissatisfaction with the camera developed in the nightcap when the outside horse, Jaber, was shown as the winner, after Captain Jinks had appeared very definitely first to practically all unofficial observers.

It must be kept in mind that the camera is not used for all races. The photograph is requested only when the judges are unable to agree upon the winner. Therefore, the race was too close to be decided by the judges, although the spectators definitely believed that the inside horse had won. This unanimity of opinion forbids its dismissal as unimportant. Perhaps it can be explained by considering the positions of the spectators. At a race track they are grouped in two stands, one in advance of, the other beyond the finish line. The spectators in the stand on the approach side of the line are prevented from accurately judging the finish of a close race because they cannot see the horses' noses. Those in the stand beyond the finish line view the horses approaching the finish. Their line of sight necessarily cuts across the track at an angle with the finish line in such direction that the horse next to the rail is favored. Although this interpretation may not be susceptible of direct proof it presents a consistent picture. If the race is nearly even with the outside horse leading, the spectators erroneously place the inside horse ahead, because of the angularity of view, and the camera is credited with having favored the outside horse. On the other hand, if the inside horse is only slightly ahead, the spectators place him farther ahead and the camera loses credit for giving a close decision to the horse next to the rail. Consequently, the belief has developed that the camera favors the outside horse.

VI. CONCLUSION

A photograph of a finish contains, within itself, evidence sufficient to determine whether or not the camera was correctly placed and whether or not the exposure was made at the proper instant. If in the photograph the finish line superposes upon its supporting post and if the winning horse has his nose on the finish line there are no errors arising from the position of the camera or from perspective. If a motion-picture camera taking 60 or more pictures per second is used, or if one employs a single-exposure camera with its focal-plane shutter arranged to photograph simultaneously the entire finish line, then the picture is without error for all horses at the finish line. Figure 3 is a picture complying with these requirements, and it is decisions rendered on pictures of this nature that have given rise to adverse criticism, which careful examination shows to be without foundation.

If a motion-picture camera is employed, the frame showing the competing horses at the finish line should be selected for enlargement and transmission to the judges. If the close decision does not involve the first horse, this frame may show the winning horse beyond the finish line.

If a single-exposure camera is used and two competing horses are less than a length behind the first horse, a picture showing the competing horses at the finish will not be available. In such a case the focal-plane shutter, if it moves from left to right, as illustrated in figure 2, will slightly favor the outside horse. On the other hand, if perspective is neglected, there will be an error from this source favoring the horse next to the rail. The error from the shutter will probably not exceed 1 inch and does not affect the horse at the finish line. The error arising from perspective can be entirely eliminated by the proper interpretation of the picture. Although these errors can exist it should be noted that their presence could not have given rise to the adverse criticism, because this criticism has been based on alleged errors in judging the first horse, whereas these admitted small errors can occur only in connection with the placing of the second and third horses.

WASHINGTON, February 3, 1937.